Forest Development Research

PROGRAM

Manning Diversified Forest Products
Research Trust Fund
MDFP 1/97
Spruce Beetle Epidemiology and
Management in NW Alberta
1997/98 Update

Alberta
ENVIRONMENTAL PROTECTION

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- Disclaimer -

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Introduction

The spruce beetle, *Dendroctonus rufipennis* (Kirby), is distributed throughout most of North America (Wood 1982). Its principal hosts in western Canada are white spruce, *Picea glauca*, and Engelmann spruce, *P. engelmannii*. The spruce beetle is one of the most destructive pests of mature spruce stands in western Canada. The biology of this species is detailed by Hiratsuka, Langor, & Crane (1995). Adult beetles attack host material in the late spring and early summer. The female bores through the bark, constructs short egg galleries in the phloem, and deposits eggs along the sides of the galleries. When eggs hatch larvae feed in the phloem until fall, when cold temperatures stop development. When temperatures increase the following spring, development continues. After a brief pupation period, new adults emerge in August and September, move to the base of trees, re-enter the bark, and overwinter. Adults in windfall or slash remain under the bark, and do not emerge until the following spring. Adults must overwinter before they can reproduce. Thus, the typical life cycle of the spruce beetle in Alberta requires two years, but may vary from 1-3 years depending on latitude, altitude, and sun-exposure.

Spruce beetles usually breed in logging slash, windthrow, cut trees, and other recently dead or weakened host material, and thus remain at relatively low population levels (endemic phase) (Dyer & Safranyik 1977). While at endemic levels, bark beetles fill vital roles in forest ecosystems by removing diseased and otherwise-weakened trees, and by contributing towards decomposition of dead coarse woody material which, in turn, increases overall forest productivity (Romme et al. 1986; Veblen et al. 1991). During times when breeding material suddenly becomes plentiful, for example, after significant windthrow or after harvesting, spruce beetle populations may quickly build up and begin to attack and kill living, and apparently healthy hosts (Safranyik et al. 1983). High populations (epidemics) may persist for several years and kill large quantities of timber over large areas (Schmid & Frye 1977). It is during such outbreaks that these beetles cause serious economic impact. Outbreaks upset harvesting schedules which are often changed to accomodate salvage logging in outbreak areas. Beetle-killed timber is suitable for pulp for many years after death (Werner et al. 1983a); however, suitability for lumber declines rapidly after death due to the action of wood-boring insects, rot fungi, and checking (Nelson 1954). Furthermore, spruce beetles vector a fungus which cause a bluish-green stain throughout much of the sapwood (Davidson 1955). Although this stained wood is sound and still suitable for lumber, it is undesirable. The increased fuel loads in stands that have experienced high beetle-caused mortality also lead to high fire (Cahill 1977).

There have been many outbreaks of spruce beetle throughout Canada over the last century, which have resulted in losses of hundreds of millions of cubic meters of wood. For example, from 1982-87 the spruce beetle killed an average of 1.9 million m^3 of spruce per year in British Columbia (Canadian Forest Service 1994). The most recent extensive outbreak of spruce beetle in northwestern Alberta occurred from about 1977-1984. The accumulated tree mortality ranged from 5-70% over a composite area of at least 100,000 ha (Moody & Cerezke 1985). Accurate volume losses are not available, but it is estimated that at least several hundred thousand m^3 of spruce were killed by beetles during this period. Spruce beetles have continued to kill trees since then, but at lower levels and in small, short-lived infestations (Brandt & Amirault 1994; Brandt 1995).

Most past effort expended on spruce beetle management in the past has simply

responded to existing outbreaks using direct suppression techniques such as pesticide application (Werner et al. 1983b; Werner & Holsten 1992), pheromones (Dyer & Safranyik 1977; Shore et al. 1990), sanitary logging (Safranyik 1989), and trap trees (Nagel et al. 1957). Although these methods occasionally control or slow the progress of outbreaks, associated costs are high. Recently, increasing efforts have been invested in developing preventative measures, including silvicultural prescriptions such as thinning and partial cutting (Hard et al. 1983; Hard 1985; Hard & Holsten 1985) and hazard rating systems (Reynolds & Hard 1991; Reynolds & Holsten 1994; Safranyik & Shore 1996). However, there is a need to determine the applicability of such measures to northwestern Alberta, and to fine-tune them for local conditions. Therefore, work to evaluate patterns of spruce beetle response to current harvesting practices and to alternative practices is advocated. A good understanding of these relationships can contribute valuable information to hazard rating systems and aid decision-making in forest management. However, elucidation of these patterns and their incorporation in planning should not be viewed as the ultimate solution to the spruce beetle problem. Long-term and effective management of the spruce beetle requires detailed knowledge of the biological processes which drive population cycles.

The epidemiology of bark beetles has been poorly studied, in part because few resources are usually available to study pest problems when they disappear, i.e., when populations decline to endemic levels. Yet an understanding of population parameters in endemic situations, and comparison to those of epidemic populations, is critical to explaining processes contributing to outbreaks. For the spruce beetle, it is therefore critical to understand which processes are responsible for the switch in host selection behaviour, from preference for dead or weakened host material to living trees, and leads to outbreaks. Factors such as fecundity, population density, mortality, starvation due to shortage of preferred host material, pheromone concentrations, or associated fungi are potentially involved in these processes. Only direct comparison of endemic and epidemic population parameters, and experimental investigations to test hypothese concerning differences, will solve unanswered questions concerning spruce beetle epidemiology, and provide a sound biological basis for long-term and effective management.

Overall Project Objectives

1. Compare endemic and epidemic populations of spruce beetle with respect to attack density, fecundity, development rate, mortality, fungal associates, and other population parameters.

2. Evaluate effects of female beetle age (since emergence), rearing density, and pheromone concentration on acceptance of live trees.

3. Evaluate the response of spruce beetle to various shelterwood and clear-cut treatments (in collaboration with Dr. Jan Volney)

4. Assess spruce beetle population changes in adjacent residual blocks following harvest,

5. Develop a hazard map for spruce forests in the Manning-Diversified FMA using the

hazard rating system developed in British Columbia (in collaboration with Dr. Terry Shore).

Project Objectives 1997/98

1. Identify specific study sites in Alberta and British Columbia and set up plots.
2. Set up controlled rearings to establish fecundity of beetles from endemic and epidemic populations.
3. Conduct pre-treatment assessment of beetle populations in all stands near Zama City identified for harvesting treatments.
4. Evaluate existing SB hazard rating system developed in British Columbia and assess its utility for NW Alberta conditions. As necessary, inventory database for availability of information required for input into hazard rating system; determine data which requires collection or refinement; prioritize stands for determination of hazard.

Materials and Methods

Controlled rearing experiment. Fecundity of beetles from endemic and epidemic populations will be investigated using artificial rearings of beetles in spruce bolts. One pair of beetles (male and female) from an epidemic population and one pair from an endemic population will be introduced into each bolt using methods developed by Langor et al. (1990). At least 50 bolts will be used in this experiment. All bolts will be screened to prevent entry of other insects. All bolts will be of similar dimensions and phloem thickness. When egg laying is complete, half of the bolts will be dissected to determine the number of eggs laid per female. Regression equations will be constructed to describe the relationship between number of eggs laid and egg gallery length. The remaining bolts will be reared until beetles reach maturity and emerge. The number of emerged beetles emerge from each gallery system will be counted and beetle size, weight, and lipid content will be determined. Mortality will be determined by comparing number of emerged beetles to number of eggs laid (estimated by using regression equations). Data will be compared among populations using ANOVA.

Response to harvesting treatments. A fully replicated experimental design to assess the local response of the spruce budworm to different levels and patterns of cutting was initiated by Dr. Jan Volney in late 1996. Treatments will consist of: 1) thinning, to create a single-storey stand by removing 25% and 50% of standing volume (Uniform Shelterwood); 2) strip cuts to remove 25% and 50% of standing volume (Shelterwood Strip Cut); 3) Clear-cuts with 'feathered edges' to remove 25% and 50% of volume; 4) a standard clear-cut currently used in operational harvesting; and 5) an untreated control (check). All eight treatments were established in a single stand and replicated four times. Spruce beetle populations were assessed over this experimental design by examining for infested wood on permanent sample plots established in each stand. Eight 50m X 2m plots were present in each stand. Additionally, in each stand where no beetle infested wood occurred on plots, a walk-through was conducted to ascertain if any SB-infested wood was present in the stand. Four Lindgren funnel traps (two in each of two stands), baited with ethanol and turpentine, were run continuously from ??? to ??? to determine the spruce beetle flight

period. Traps were emptied every 2-3 weeks and insects returned to the lab for identification.

Hazard rating. We will collaborate with Dr. Terry Shore to calibrate, if necessary, the newly-developed hazard rating system for use in spruce forests in NW Alberta, starting with those on the Manning-Diversified sphere of influence. Stands will be assessed for risk factors such as site quality, stand age, stand density and growth rate, stand location, percentage of spruce beetle-susceptible basal area, proximity of disturbance (logging, windthrow, fire). These data will be obtained from the existing inventory database and by surveys (e.g. Shore & Safranyik 1992) The ratings for these criteria will be used to calculate the hazard index. The product of this work will be a map showing areas of low, medium, and high hazard. This information can be used for making decisions about harvesting schedules.

Progress: Results & Discussion

Study sites. A study of the epidemiology of the spruce beetle requires study of populations in the endemic and epidemic (outbreak) phase. Spruce beetle populations throughout Alberta are currently in the endemic phase. Suitable stands of mature white spruce containing endemic beetle populations were located west of the Manning Diversified Forest Products mill yard and on Zama Ridge. In future years, experiments will be established at these sites to study the important characteristics of endemic populations.

Considerable effort was spent in trying to locate outbreaks in adjacent parts of British Columbia and the Northwest Territories, without success. The closest outbreak was found in the vicinity of Prince George, BC. Material from this outbreak was collected for use in controlled rearings (see below).

Controlled rearing experiment.

Beetles from endemic populations were collected from near Manning and Zama Ridge in Alberta. These were reared from infested bolts in which they were overwintering. Logs containing spruce beetles were also collected from an outbreak area north of Prince George. These were returned to Edmonton and reared to obtain adult beetles. However, the rearing process resulted in high mortality among the population from Prince George, likely due to a disease agent, and insufficient beetles were obtained to establish this experiment. This experiment will be attempted again in 1998

Response to harvesting treatments.

In 1996 the boundaries of the 32 experimental stands were laid out on Zama Ridge. In 1997, these stands were assigned treatments (Fig. 1) and plots were established. Catches from Lindgren funnel traps indicated that spruce beetles flew up until the end of August (Fig. 2). There was no distinct flight peak, but it is possible that this occurred in late May before traps were deployed. Most reports of spruce beetle flight phenology state that peak flight occurs in late May and early June (refs).

Throughout August and September, plots were monitored for spruce beetle activity. Spruce beetle populations were very low (endemic) in all stands. Spruce beetle-infested wood was found on only 3 of the 256 plots. However, a walk-through of all stands revealed that beetle-infested material was present in low abundance in all stands. All stands had <1 m^3/ha of spruce beetle-infested wood. It is possible that some of the large trees infested with spruce beetle may be harvested during application of the treatments during the winter of 1997/98. Therefore, during assessment of spruce beetle populations in 1998 it will be necessary to also look for wood from which beetles emerged in 1998 in order to ascertain the baseline population level immediately after application of treatments.

Hazard rating.

For a number of years, a susceptibility and risk rating system for spruce beetle has been under development by Dr. Terry Shore and Dr. Les Safranyik at the Pacific Forestry Centre in Victoria. This system was developed in the interior of British Columbia and has recently been extensively tested in the Merritt Forest District and the Prince George Forest Region of BC. I had some initial concerns whether this system, developed for interior spruce forests, would be directly applicable to boreal white spruce forests in NW Alberta. In consultation with Drs. Shore and Safranyik, through examination of the current version of the risk rating system (version 4) and comparison of its key components to published and unpublished knowledge about causes of outbreaks in boreal spruce forests, and observations of the system in action (available on the internet), we conclude that the system is robust enough to be fully applicable to NW Alberta conditions. Thus, it is recommended that the forest industry in NW Alberta commence applying this hazard rating system to spruce stands in their FMAs and leases to an attempt to develop a comprehensive assessment of the risk of spruce beetle outbreaks in northern spruce.

The approach used by Shore and Safranyik considers the short term risk of loss to a stand as a function of both stand susceptibility and beetle population pressure. The risk rating system requires input of a specific set of data in order to calculate a measure of risk. Some of this data is readily available but some will have to be specifically collected for input into this hazard rating system.

The risk rating system has two major components: 1) an assessment of **stand susceptibility** to spruce beetle attacks (this includes measures of stand mensurational and characteristics and location); 2) an assessment of **beetle population pressure** (measure of the amount of breeding material in stands or adjacent which influence beetle population size and, subsequently, the chances that an outbreak may occur in standing live trees). Either of these components may be calculated and used by themselves, but the risk rating system is much better if both are incorporated.

The data required for a stand in order to calculate the **stand susceptibility index** are:

1. Site Quality - this is simply a qualitative assessment of the site quality as good, medium, or poor according to established criteria. Risk increases with increased site quality.
2. Stand Age - measure of age of dominant/co-dominant spruce. Three categories are used: >120 years, 100-120 years, <100 years. Risk increases with age.

3. Stand Density/Growth Rate - two measures are required:
   a. number of spruce per hectare with DBH ≥25 cm;
   b. mean radial growth of spruce during the last 5 years (in mm). It is realized that measurement of mean radial growth is labor intensive and not standardly collected in most inventories, so a mathematical equation which takes into account the number of trees of all species per hectare with a DBH ≥7.5 cm may be used as a proxy of mean radial growth.

4. Basal area of susceptible spruce - two measures are required:
   a. Basal area (m^2/ha) of spruce with DBH ≥25 cm.
   b. Basal area of all tree species with DBH ≥7.5 cm.

5. Stand Location - three measures are required:
   a. Latitude and longitude.
   b. Elevation (m).
   c. Aspect.

The scores resulting from each of these five measures are multiplicative and result in a Stand Susceptibility Index which ranges from 0 to 100. Higher numbers indicate higher risk.

The data required to calculate the **beetle pressure index** are:

1. Windfall - a measure of recent (1-3 years old) windfall in the stand being assessed or, in some cases, in adjacent stands. For scattered windfall, a measure of the mean number of trees per 100 m transect across stand openings or along stand edges is required. If there is sheet windfall within the stand or within adjacent stands, a measure of the size of the affected area is required (>50 ha, 10-50 ha, <10 ha).
2. Standing Infested Trees - three measures are required:
   a. Distance to the nearest spruce beetle attack (in stand, or distance from stand to the nearest km).
   b. Number of trees per ha infested with beetles within the stand (≤1, 2-6, >6).
   c. Number of trees per ha infested with beetles within 3 km of stand (same categories).
3. Logging - A measure of the size (ha) of recent (≤2 years old) logging operations in adjacent stands (>100 ha, 50-100, 20-49, 5-19, <5).
4. Fire History - A measure of the size (ha) of recent (≤2 years old) fires in adjacent stands (same categories as for logging).

Each of these four measures will produce a score. The beetle pressure index is calculated as the highest value among these four scores. This index will range from 0 to 1. Higher numbers indicate higher risk.

Finally, the stand susceptibility index and beetle population pressure index may be combined into a **risk index** using a complicated equation. This index ranges from 0 to 100 and a higher number indicates higher risk.

I have not provided the equations for calculation of scores and indices since a computer program is available through the internet to do this automatically once the appropriate data have been entered. The web page for this program is:
http://www.pfc.cfs.nrcan.gc.ca/landscape/beetle/spruce/sprucerr.html
A sample of the page and its prompts are attached as an appendix.

Recommendation: If the forest industry in NW Alberta is interested in applying this hazard rating system to their FMAs and leases, it is important that they assess which data are available now (or will be in the near future due to ongoing inventories) and ascertain how to collect the additional data required to allow the risk rating system to be applied. At the very least, a **stand susceptibility index** should be calculated. This will help industry identify stands which are at highest risk and allow them the option of adjusting harvesting schedules to remove these stands. Since, recent and ongoing surveys by the Canadian Forest Service, Alberta Land & Forest Service, and the forest industry have revealed that there are no notable outbreaks of spruce beetle in NW Alberta, perhaps some shortcuts could be taken to easily calculate a **beetle pressure index** in the following way:

1. Windfall - if there appears to be substantial scattered windfall along stand edges bordering openings (e.g. clearcuts, fires, natural openings) of some stands or if there is any sheet windfall, attempts should be made to get an accurate measure. If this situation occurs we can assume the lowest score (0.2).
2. Standing infested trees - these are very rare now and very scattered. Unless some concentrations of newly faded infested trees are discovered, it is probably safely to apply the lowest score (0.2) to this item.
3. Logging - the area of recent adjacent logging is easily obtained to give an accurate score.
4. Fire - the area of recent adjacent fire is easily obtained to give an accurate score.

The highest of these 4 scores will give the beetle pressure index which can then be combined with the stand susceptibility index to give an overall risk rating. I am available at anytime to assist in the application of this risk rating system to the land base.

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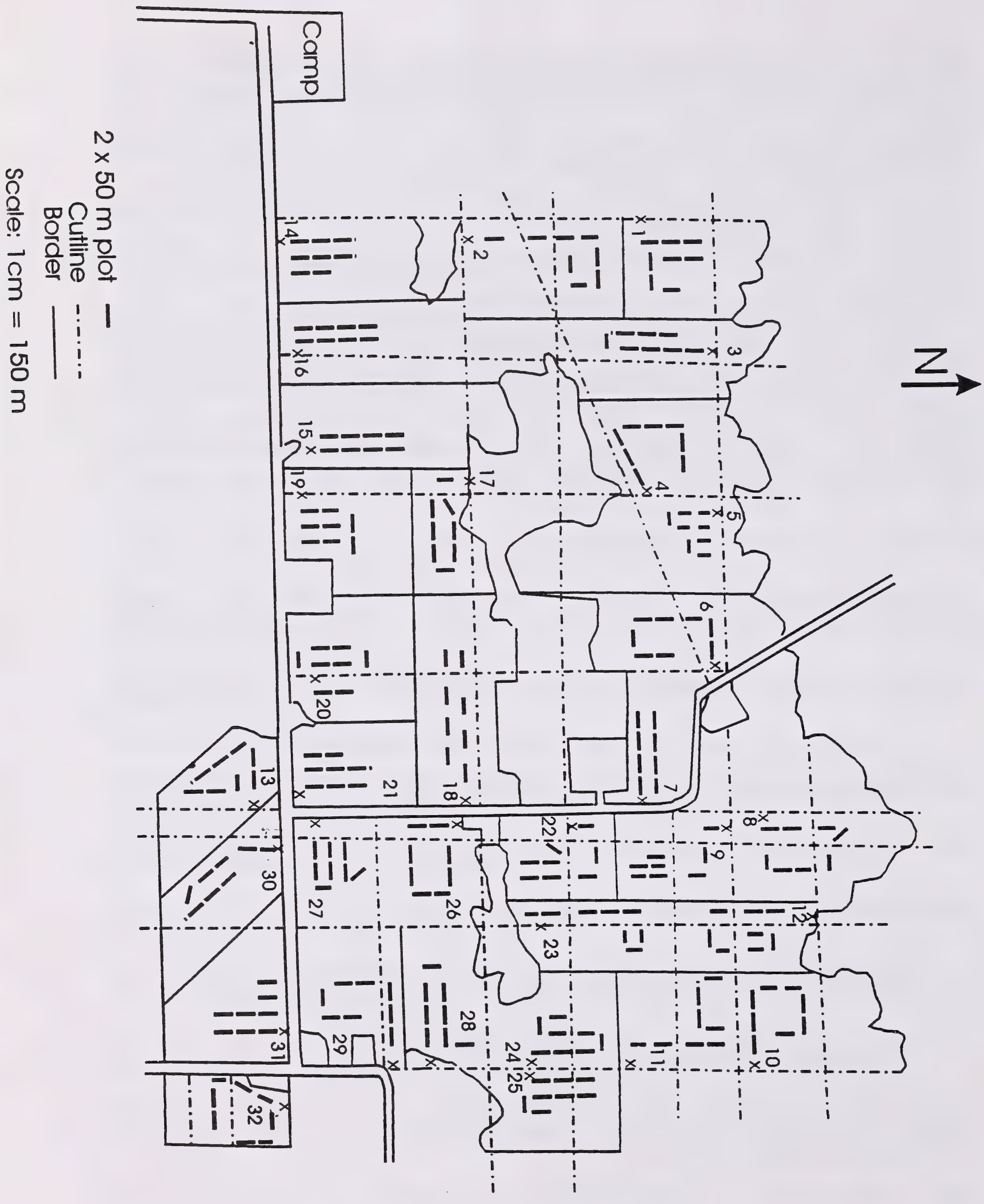


Figure 1. Layout of silvicultural experiment at Zama ridge

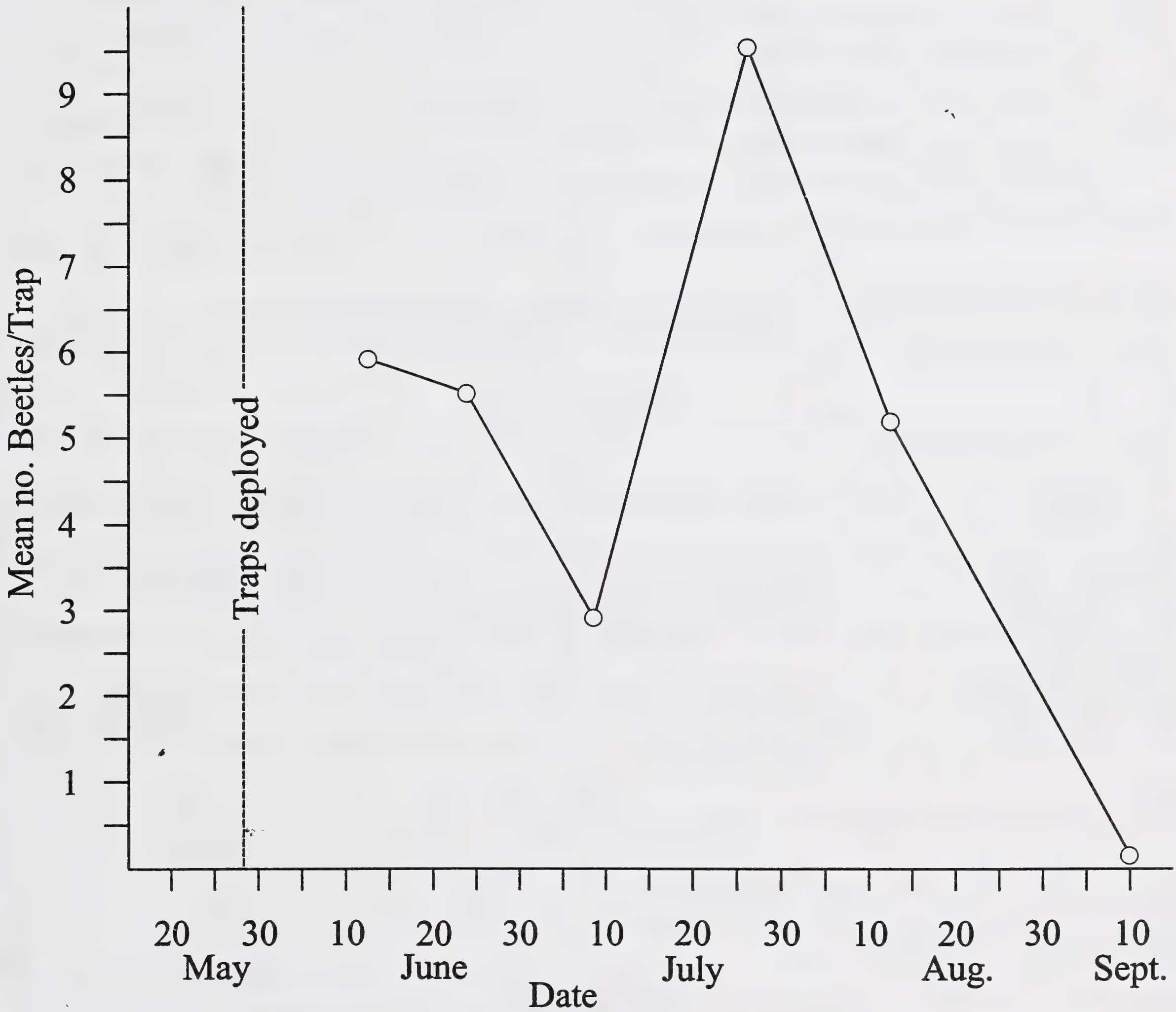


Fig. 2. Flight period of spruce beetle at Zama Ridge, Alberta, 1997. Traps were deployed May28

Appendix

Spruce Beetle

Risk Rating Page

This page contains a form that requests certain information about a forest stand that is to be rated for risk potential of an attack by Spruce Beetle.

Please fill in the following fields. If you wish to compute only the Stand Susceptibility, fill in all fields for **Stand Composition** and **Stand Location**. If you wish to compute only the Beetle Pressure Index, fill in all fields in **Beetle Pressure Information**. To compute the Risk Rating Index, fill in **all** fields.

When you have completed filling in the data fields, click "Evaluate!" to view the Risk Rating for the stand.

(Note that if your browser is incapable of reading JavaScript, this page will not work properly.)

Stand Composition	
Site Quality	Good ▾
Average Age of Dominant/Codominant Spruce Trees in the Stand	less than 100 years ▾
Average Basal Area of Spruce Trees in the Stand (DBH >= 25cm)	m^2/ha
Average Basal Area of All the Species in the Stand (DBH >= 7.5cm)	m^2/ha
Tree Density (Stems per Hectare, DBH >= 25cm)	
Mean Radial Growth of Spruce in Last 5 Years) ◉ The entered value is the amount of growth (mm). ○ The entered value is the number of trees in the stand (all species, DBH >= 7.5cm), from which the growth rate is to be estimated.	
Stand Location	
Latitude	North ▾
Longitude	
Elevation	m.
Beetle Pressure Information	
Distance to Nearest Spruce Beetle Attack	in stand ▾ — category
Number of Trees Infected by Spruce Beetle Within the Stand	0 or 1 ▾ per ha. category
Number of Trees Infected by Spruce Beetle Within 3 km. of the Stand	6 or fewer ▾ trees

Logging: Size of Cutblocks Within Last 2 Years	more than 100 hectares
Fire: Size of Fire Within Last 2 Years	more than 100 hectares

Windfall --- select one of the following options:

- (•) Mature spruce windfall, down one to three years scattered in the stand or small patch blowdown averaging **more than 2 trees** per 100m transect across opening or **more than 5 trees** per 100m along stand edges.
- ( ) Mature spruce windfall, down one to three years scattered in the stand or small patch blowdown averaging **between 1 and 2 trees** per 100m transect across opening or **between 2.5 and 5 trees** per 100m along stand edges.
- ( ) Mature spruce windfall, down one to three years scattered in the stand or small patch blowdown averaging **less than 1 tree** per 100m transect across opening or **less than 2.5 trees** per 100m along stand edges.
- ( ) Sheet windthrow **greater than 50** hectares in the stand or the adjactent stands being assessed.
- ( ) Sheet windthrow **between 10 and 50** hectares in the stand or the adjactent stands being assessed.
- ( ) Sheet windthrow **less than 10** hectares in the stand or the adjactent stands being assessed.

Evaluate!

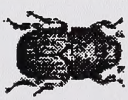
RESULTS

Stand Susceptibility [ ] Beetle Pressure [ ]

Risk Rating [ ]

Clear All Fields

Stand Susceptibility: 0 - 100
Beetle Pressure: 0 - 1
Risk Rating: 0 - 100
* *higher numbers indicate greater risk*



[Bark Beetle Home] [Decision Support Home]